



CE Workgroup

Status of Embedded Linux September 2017

Tim Bird

Architecture Group Chair

LF Core Embedded Linux Project



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Nature of this talk...

- Quick overview of lots of embedded topics
- A springboard for further research
 - If you see something interesting, you have a link or something to search for



CE Workgroup

Outline

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources



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Kernel Versions

- Linux v4.7 – 24 July 2016 – 70 days
- Linux v4.8 – 2 Oct 2016 – 70 days
- Linux v4.9 – 11 Dec 2016 – 70 days
- Linux v4.10 – 19 Feb 2017 – 70 days
- Linux v4.11 – 30 Apr 2017 – 70 days
- Linux v4.12 – 2 Jul 2017 – 63 days
- Linux v4.13-rc7
 - v4.13 expected on 3 Sep, 2017 (*would be 63 days*)



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Linux 4.7

- Schedutil frequency governor
 - Use the load calculated by the scheduler instead of the average load over past little while
 - See <http://lwn.net/Articles/682391/>
- VFS layer can iterate through directories in parallel
- Ability to attach BPF programs to tracepoints
- Ftrace histograms
 - Can tell tracer to accumulate events into buckets and give results, via the sysfs interface



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Linux 4.8

- New kernel documentation system
 - Based on Sphinx
 - See <https://lwn.net/Articles/692704/>
- New pseudo-random number generator
 - See <https://lwn.net/Articles/686033/>
- ARM64 support for kexec and kprobes
- New timer wheel implementation
 - <https://lwn.net/Articles/646950/>
 - Better performance:
 - No more cascade operations
 - Quick determination of next timeout
 - Automatically coalesces longer timeouts
 - Long timeouts have reduced resolution



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Linux 4.9

- Virtually mapped kernel stacks
 - <http://lwn.net/Articles/692953/>
 - Allows to detect stack overruns
 - Cleans up kernel code, faster process creation
 - Only on x86, for now
- **Greybus** - <https://lwn.net/Articles/715955/>
- Timed samples for eBPF
- Modversions deprecated
 - See <https://lwn.net/Articles/707520/>



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Linux 4.10

- Perf sched timehist
- Hybrid block polling
 - Supports polling for block I/O, but with a short delay (estimated) before the polling starts
 - Improves performance by queuing blocks as soon as device is ready (via polling)
 - Uses less CPU than full polling
- Support for ARM SoCs:
 - Huawei, Allwinner, Marvel, Renesas
- Posix timers are configurable
- Initramfs compression method is selectable
- New interface for system sleep state selection
 - `/sys/power/mem_sleep`
- UBIFS support for encryption



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Linux 4.11

- New kernel refcount API
- TinyDRM subsystem added
- New statx() system call
 - <https://lwn.net/Articles/707602/>
 - 2038-safe time values
 - Mask of fields to obtain (for efficiency)
- Sched.h refactoring
 - Non-mainline code: watch out!



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Linux 4.12

- BFQ and Kyber block I/O schedulers
- Minitty prep work
 - Not full minitty implementation yet
- Proper support for USB type-C connectors
- AnalyzeBoot tool
 - Reads dmesg (and possibly ftrace log) and produces html graph of boot events
 - Part of Intel pm-graph tools project
 - <https://github.com/01org/pm-graph>
 - See tools/power/pm-graph/analyze_boot.py



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Linux 4.13 (expected)

- TLS implementation in the kernel
 - Should help with HTTPS performance
 - See <https://lwn.net/Articles/666509/>
- Next-interrupt prediction
- F2FS support for disk quotas
- Kselftest transitioning to TAP13 protocol



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Bootup Time

- Analyze_boot tool – new in in 4.12
- Some good previous talks:
 - ELCE 2014 - *12 Lessons Learnt in Boot Time Reduction* by Andrew Murray
 - ELC 2015 - *Fastboot Tools and Techniques* by John Mehaffey
- Android boot time ideas
 - ELC 2017 – *Improving the bootup speed of AOSP* – Bernhard Rosenkranzer



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Bootup ideas from Bernhard

- Two approaches:
 - Improve cold boot
 - Enhance suspend/resume
- Areas analyzed for cold boot:
 - Package Manager scanning
 - Java class preloading
 - PM: force high CPU frequency during boot
 - IO: read-ahead, kernel compression, squashfs
 - Kernel modules – defer modules until later
 - Library and compiler optimizations



Device Tree

- Device Tree Overlays
 - Allow plugin-boards to be configured at runtime
 - Session at ELC 2016 by Pantellis
 - **Not mainlined yet? – expected in 4.11?**
- Device Tree validation
 - Schema for binding language, validator for bindings and for device tree data
 - **This work stalled**
 - **New proposal for device tree in YAML format**
 - <https://lwn.net/Articles/730217/>
- Updated Device Tree specification
 - Want to update material and make it more available
- See http://elinux.org/Device_tree_plumbers_2016_etherpad
 - And ELC 2017 Device Tree BOF – Frank Rowand



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Graphics

- TinyDRM
 - Provides graphic support for small simple displays (eg displays over i2C or SPI)
 - Hope to replace framebuffer drivers over time
 - See https://www.phoronix.com/scan.php?page=news_item&px=TinyDRM-Patches-Posted
- Presentation
 - ELC 2017 *What Can Vulkan do for You?* - by Jason Ekstrand



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GPU drivers

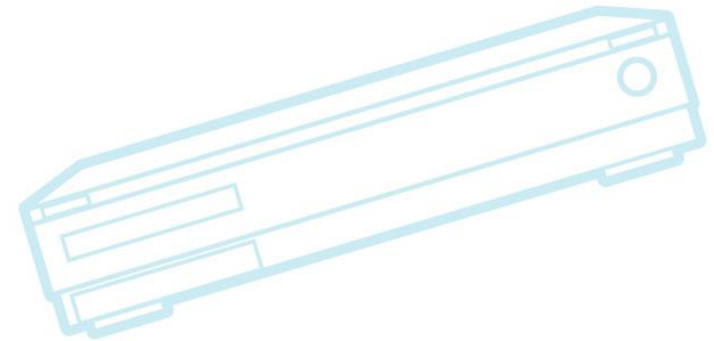
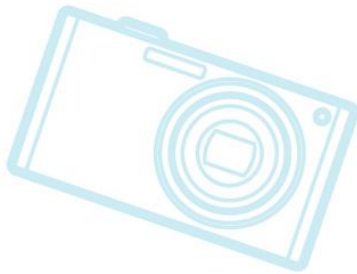
- Nvidia, Vivante and Broadcom GPUs have open drivers
 - Nouveau, Etnaviv, and VideoCore 4
- Qualcomm Adreno
 - Freedreno continues to be developed (June 2017)
 - See <https://www.xda-developers.com/open-source-adreno-project-freedreno-receives-new-update/>
- Imagination PowerVR – no public driver, although one was teased in 2015
 - Apple dropping Imagination (April 2017)
- ARM Mali – Some work (Lima project) on earlier chip versions, nothing lately
 - Status update: <https://lwn.net/Articles/716600/>
 - No open source drivers likely



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File Systems

- UBIFS support for encryption (in 4.11)
- IO scheduling for solid state storage
- LightNVM
 - Software control of flash-translation layer
 - <https://lwn.net/Articles/641247>
- F2FS support for disk quotas (in 4.13)





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Networking

- Bluetooth:
 - Bluetooth 5.0
 - Most features are on BLE codebase
 - Only 1 for “BL classic”
 - 800% data throughput increase
 - 4 times the range
 - Coexistence with wireless
 - Better error correction to handle noisy environments



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Power Management

- New interface for system sleep state (in 4.10)
 - `/sys/power/mem_sleep`
- Power-efficient workqueues
 - More efficient work scheduling
 - Results in about 15% better energy consumption
 - See <https://lwn.net/Articles/731052/>
- Operating-System-Directed Power-Management Summit
 - <https://lwn.net/Articles/721573/>
 - Energy-aware scheduling
 - A collection of scheduling talks that will make your head spin



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Real Time

- SCHED_DEADLINE
 - ELC 2017 - *SCHED_DEADLINE: It's Alive* - by Juri Lelli
 - Energy Aware Scheduler support
 - Bandwidth reclaiming
 - Temporarily allow a task to exceed it's bandwidth, if no other process' deadline suffers
 - Support for Frequency scaling
 - Group scheduling
- Presentations:
 - ELC 2017 *Effectively Measure and Reduce Kernel Latencies for Real-time Constraints* – By Jim Huang
 - ELC 2017 *Real-Time Linux on Embedded Multicore Processors* – by Andres Ehmanns



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Security

- Kernel hardening
 - http://kernsec.org/wiki/index.php/Kernel_Self_Protection_Project
 - Rare_write infrastructure
 - Keep some code and data read-only most of the time
 - <https://lwn.net/Articles/724319/>
 - GCC plugins for kernel security
 - Kernexec
 - Prevent kernel from executing user-space code
 - Structleak (mainlined in 4.11)
 - Zero out kernel structures passed to user space, under some conditions
 - See <https://lwn.net/Articles/712161/>
 - Randstruct
 - Randomize C structure layout
 - See <https://lwn.net/Articles/722293/>



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Security Presentations

- ELC 2017 *Securing Embedded Linux Systems with TPM 2.0* – by Philip Tricca



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System Size

- Initramfs compression method is selectable
- Nicolas Pitre work
 - Configurable POSIX timers – in v4.10
 - <https://lwn.net/Articles/701095/>
 - Mini TTY
 - Smaller implementation of TTY subsystem, for embedded
 - Saves about 38K
 - <https://lwn.net/Articles/721074/>
 - People wanted refactoring of full-size TTY instead of new small implementation, but Nicolas said that wasn't feasible



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System Size (cont.)

- Shrinking the scheduler
 - Drops features and eliminates realtime and deadline scheduler classes
 - Saves about 20k
 - <https://lwn.net/Articles/725376/>
 - Lots of resistance to this
 - Code complexity increase is not worth saving 20k (according to Ingo Molnar)
 - Disagreement on whether Linux should support computers with sub-1MB memory



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Size Presentations

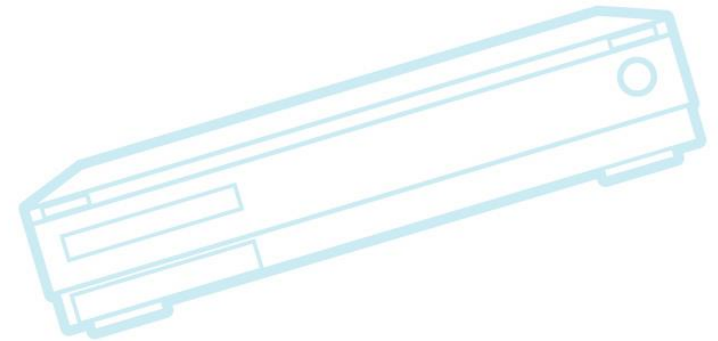
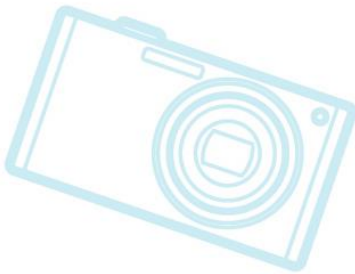
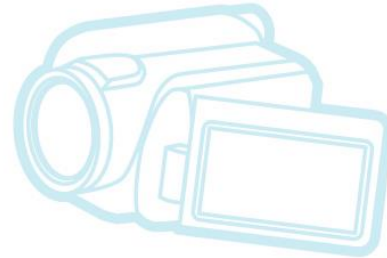
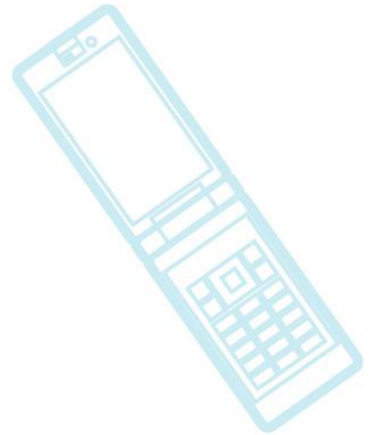
- LinuxCon North America: *Running Linux on Tiny Peripherals* – by Marcel Holtmann
 - Got Linux to around 1MB for IOT sensor project
- ELC 2017 *Embedded Linux Size Reduction Techniques* – By Michael Opdenacker
 - Very good overview of existing reduction techniques and status
 - Formal Tinification project is stalled
 - Toybox and musl (smaller libc) are worth looking at



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Testing

- Kselftest
- Fuego
- Kernelci.org
- LAVA V2





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Kselftest

- Unit test system inside kernel source tree
- Recent work:
 - Lots more regression tests (preferred place for syscall compatibility/regression tests (over LTP))
 - Converting to TAP (Test Anything Protocol) for test output (started in 4.13)



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Fuego

- New Test Framework for collaborating on tests and test infrastructure for Linux
- V1.1 features (April 2017)
 - Upgrade to latest Jenkins
 - Test script refactoring
 - Fuego container directory layout change
 - About 40 new tests
- V1.2 plans (RC very soon (Sep 2017))
 - Unified output format
 - Convert all test results to JSON, in a format compatible with Kernel CI
 - New pass criteria system
 - Test dependency system
 - Board dynamic variables



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Kernelci.org

- Place to get free build/boot testing for your board
 - Builds 126 trees continuously, then reports any errors
- <http://kernelci.org>
- Presentations:
 - ELC and ELCE 2016 – by Kevin Hilman
 - Linaro Connect:
 - Kernelci and lava update - See <https://lwn.net/Articles/716600/>
- The most successful public, distributed build and test system for Linux, in the world!



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LAVA

- Linaro Automation and Validation Architecture
- V2
 - Job files now use Jinja2 templates
 - Was previously hand-written JSON
 - Jobs are run asynchronously, without polling,
 - ZeroMQ is used for communications.
 - ReactOBus is used to run jobs from messages.
 - Requires more explicit board configuration



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Toolchains

- LLVM 4.0.0 is released
 - Some code size improvements from optimizations (GVNHoist)
 - Experimental support for LLVM coroutines
 - <https://lwn.net/Articles/716979/>
- Presentations:
 - ELC 2017 - *GCC/Clang Optimizations for Embedded Linux* – by Khem Raj



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Tracing

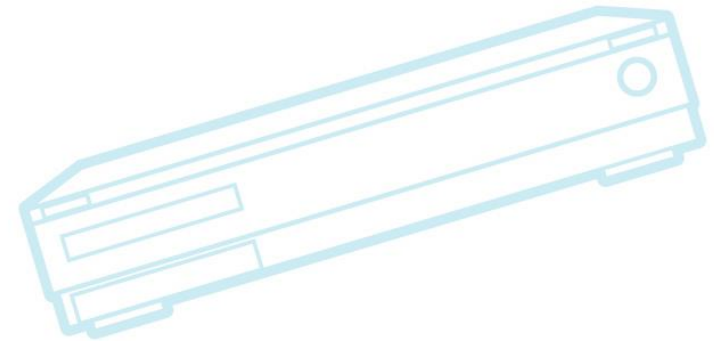
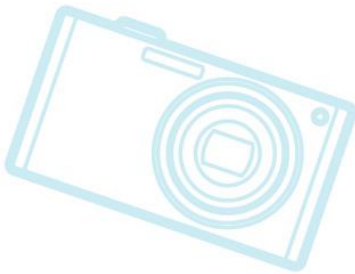
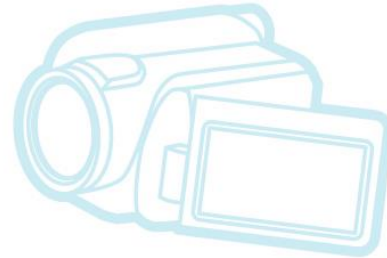
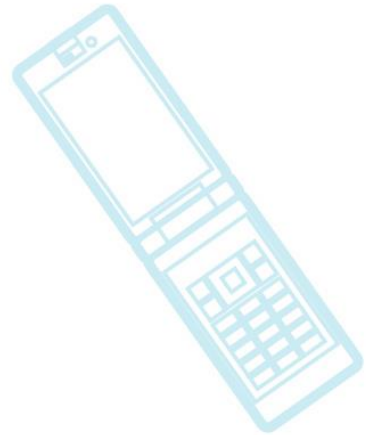
- More perf tools (both in 4.10):
 - perf sched timehist
 - Analysis of scheduling events
 - perf c2c
 - Cacheline contention analysis
- Presentations:
 - ELC 2017 *Dynamic Tracing Tools on ARM/AArch64 Platform: Updates and Challenges*
 - by Hiroyuki Ishii
 - Great overview



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Miscellaneous

- Printk issues
- Year 2038 work
- Linus issues with Kconfig
- AGL making inroads





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Printk issues

- Discussion on kernel summit mailing list
 - Lots of issues with printk
 - It's not per-CPU, console lock held too long, it has complicated code paths, and lots more
 - See thread start at:
 - <https://lists.linuxfoundation.org/pipermail/ksummit-discuss/2017-June/004358.html>
- Recent discussions about KERN_CONT
 - KERN_CONT is unreliable for SMP kernels
 - Latest kernelput '\n' between lines that don't have KERN_CONT
 - Eventual removal of KERN_CONT
 - Maybe use of seq_buf for outputting serialized data atomically
 - <https://lwn.net/Articles/732420/>



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Year 2017 work

- 3 areas of work
 - Converting all 32-bit timestamps to 64-bit in the kernel
 - e.g. New statx() system call
 - Many patches are in-progress (vfs layer, v4l, device-mapper, input subsystem)
 - C libraries
 - Lots of work in glibc to make everything backwards compatible
 - Even programs built with 32-bit timestamps should work
 - Distribution builds – fixing up individual packages
- See <https://lwn.net/Articles/717076/>



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Linus issues with Kconfig

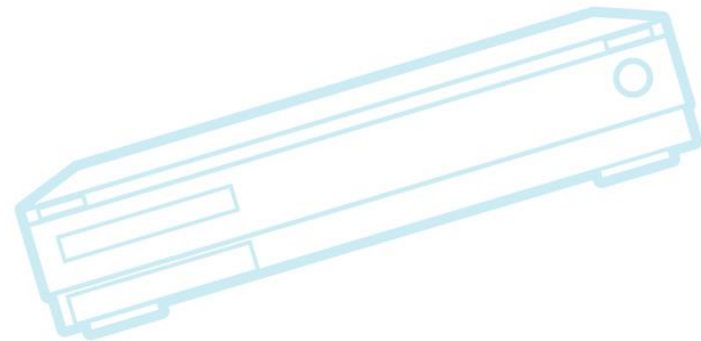
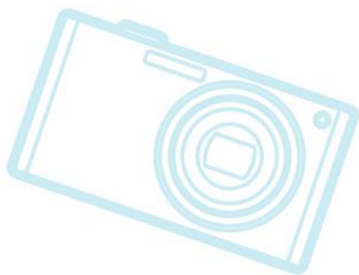
- Discussion on kernel summit mailing list
 - Kconfig is too hard for end users
 - What can be done?
 - Linus' complaint:
 - <https://lists.linuxfoundation.org/pipermail/ksummit-discuss/2017-June/004504.html>
- Ideas:
 - Config fragments
 - Higher level options
 - Better dependencies
 - From distro feature to kernel config



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AGL status

- First car in US with Entune (AGL-based infotainment OS) will be 2018 Toyota Camry
 - Announced at Open Source Summit Japan by Toyota
- Mazda and Toyota collaborating on Entune
 - https://www.theregister.co.uk/2017/08/29/mazda_toyota_linux_entune_car_infotainment/





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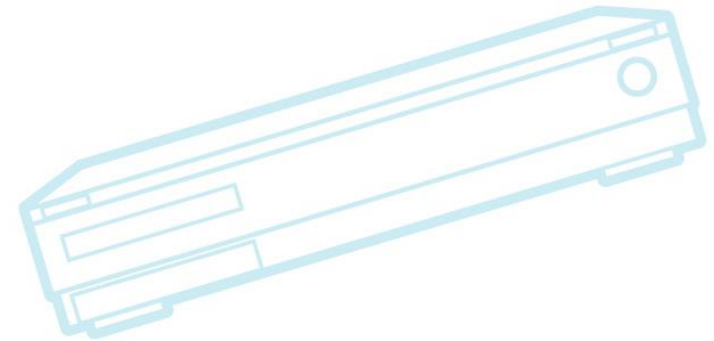
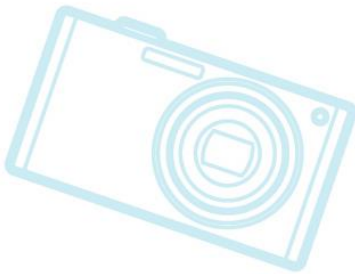
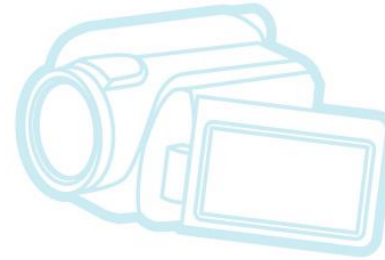
Resources



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Projects and initiatives

- Shared Embedded Distribution
- LTSI
- Fuego
- eLinux wiki





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Shared Embedded Distribution

- Goals
 - Create an industry-supported distribution of embedded Linux
 - Main goal is very long term support (15 years)
- Status
 - Toshiba has created Yocto layer meta-Debian
 - Presented at ELCE, ELC, and LCJ
- Next steps
 - Improve coordination with Debian community



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Long Term Support Initiative

- LTSI 4.9 is current LTSI kernel
 - Work is in progress on next release
- GregKH said
 - Expected delivery date: Sep 2017
 - Converting to upstream-first policy
- Presentation:
 - ELC 2017 *Using Linux as Long Term Working with the Community* – by Tsugikazu Shibata



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Fuego - Linux Test Framework

- Working on lots of issues:
 - Command line tool
 - Test packaging
 - LAVA integration
 - Serial console transport
- Presentation:
 - ELC 2017 *BoF: Fuego Status and Roadmap* – by Tim Bird



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eLinux wiki

- <http://elinux.org>
 - Web site dedicated to information for embedded Linux developers
 - The wikipedia of embedded linux!
- Hundreds of pages covering numerous topic areas: bootup time, realtime, security, power management, flash filesystem, toolchain, editors
- **Slides and Videos for 12 years of ELC!!**
- Please use and add to site



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Trade Associations

- Linaro still doing lots of great work
 - Lava v2 and kernelci
 - Now promoting Zephyr
 - Linaro Connect consistently has useful material
- Linux Foundation
 - Continuing to grow
 - First event in China sold out in 2 weeks (1200 attendees)
 - Over 100 conferences, 67 projects
 - Not just Linux
 - More than 500 members



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Conferences

- ELC 2017
 - Lots of great sessions
 - See: http://elinux.org/ELC_2017_Presentations
- Open Source Summit Japan
 - May 31-June 2, Tokyo
- Embedded Linux Conference Europe
 - October 23-25, Prague, Czech Republic
- Embedded Linux Conference 2018
 - March 12-14, Portland, Oregon, USA
- Japan Jamborees
 - Continuing



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Closing thoughts

- Google search oddity
- How is Linux doing in embedded
 - AspenCore/EETimes/embedded survey of embedded market 2017



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Google search “linux kernel”

- Tux seems a bit off...

The screenshot shows a Google search for "linux kernel" on a desktop browser. The search results page displays several links, including "The Linux Kernel Archives", "Linux kernel - Wikipedia", and "GitHub - torvalds/linux: Linux kernel source tree". A knowledge panel on the right side of the page provides a summary of the Linux kernel, including its description as a monolithic Unix-like computer operating system kernel, its developer (Linus Torvalds and thousands of collaborators), its written language (C and assembly), its latest release (4.12.8), its initial release (0.01), its latest preview (4.13-rc6), and its OS family (Unix-like). The knowledge panel also features a small image of Tux the penguin.

Google search results for "linux kernel".

Search results include:

- The Linux Kernel Archives
- Linux kernel - Wikipedia
- GitHub - torvalds/linux: Linux kernel source tree
- Commits · torvalds/linux · GitHub

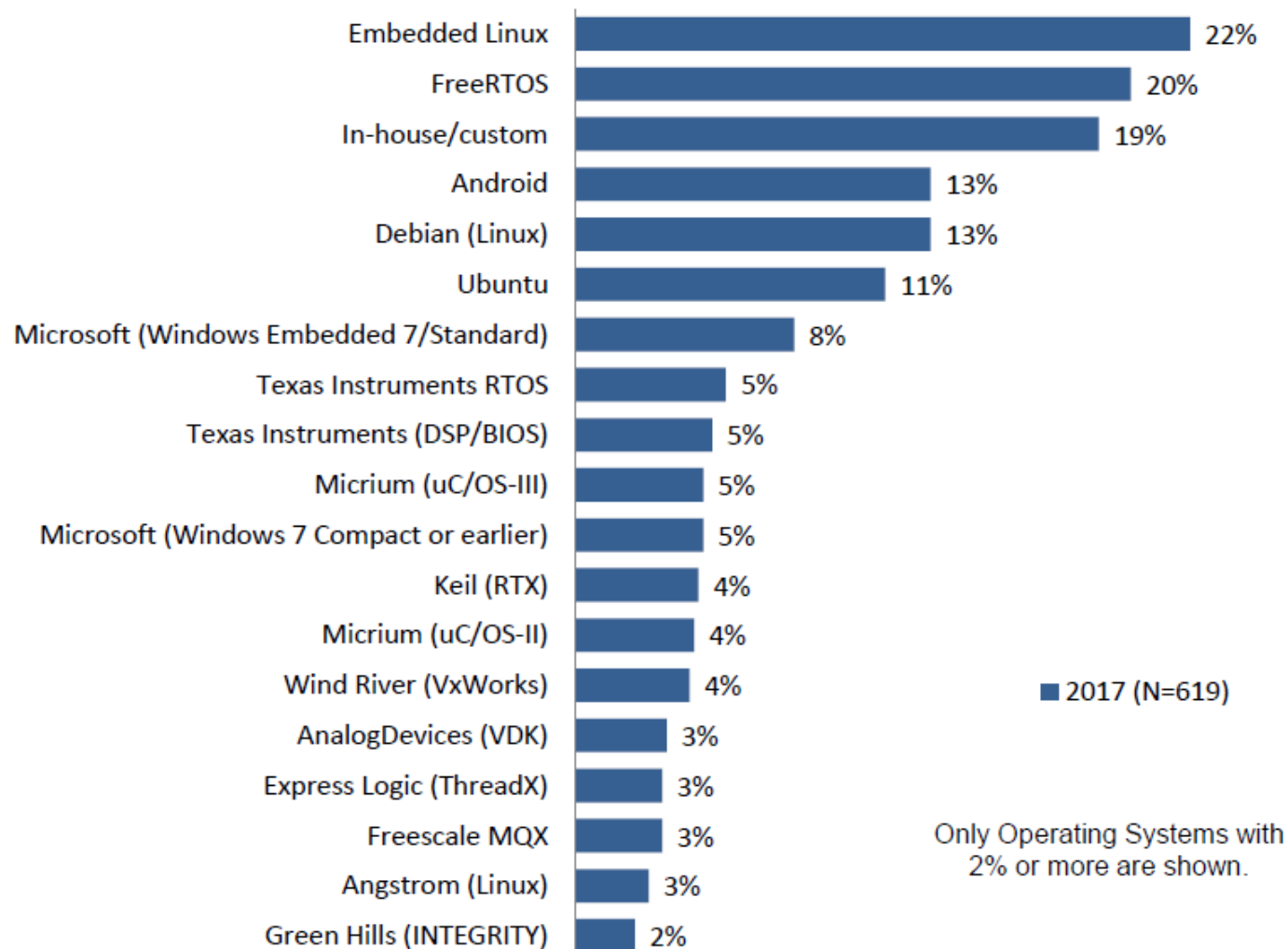
Knowledge panel details:

- Linux kernel**
- Operating system
- The Linux kernel is a monolithic Unix-like computer operating system kernel. The Linux family of operating systems is based on this kernel and deployed on both traditional computer systems such as ... [Wikipedia](#)
- Developer:** Linus Torvalds and thousands of collaborators
- Written in:** C and assembly
- Latest release:** 4.12.8 (16 August 2017; 7 days ago)
- Initial release:** 0.01 (17 September 1991; 25 years ago)
- Latest preview:** 4.13-rc6 (20 August 2017; 3 days ago)
- OS family:** Unix-like



ASPENCORE

Please select **ALL** of the operating systems you are currently using.



Base: Currently using an operating system



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Survey notes

- Embedded Linux at 22 percent
 - But if you include Android, Debian, Ubuntu and Angstrom – it's 61%
 - If you can add them – which is unclear
- Article:
<https://www.linux.com/news/event/elce/2017/linux-and-open-source-move-embedded-says-survey>
- Source:
<http://m.eet.com/media/1246048/2017-embedded-market-study.pdf>



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Despite goofy Tux,
world domination is proceeding
as planned...



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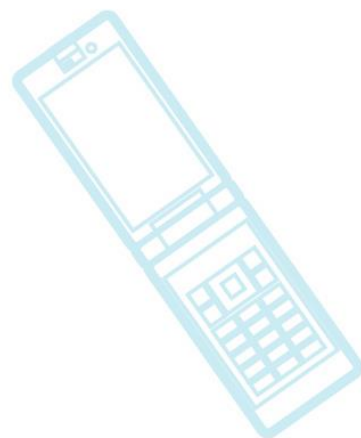
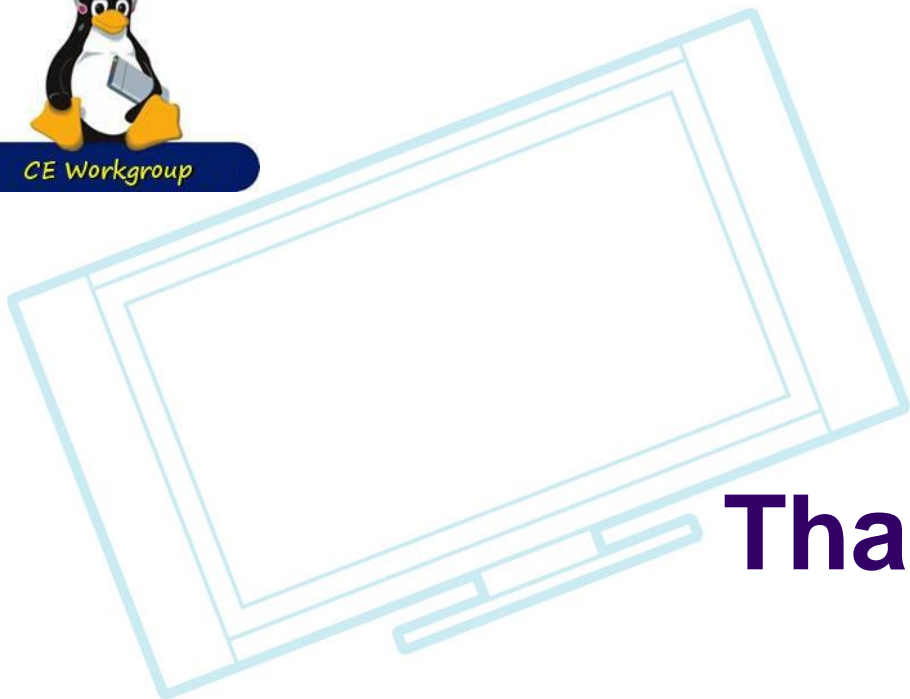
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Resources

- LWN.net
 - <http://lwn.net/>
 - If you are not subscribed, please do so
- Kernel Newbies
 - http://kernelnewbies.org/Linux_4.??
- eLinux wiki - <http://elinux.org/>
 - Especially <http://elinux.org/Events> for slides
- Celinix-dev mailing list



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Thanks!

